

CLAIMS

We claim:

1. An apparatus for reacting chemicals to produce products and for separating the products, comprising:

5 a reaction vessel having a first zone with a first reactor and first distillation stage and a second zone with a second reactor and a second distillation stage;

said first and second reactors producing the products and said first and second distillation stages separating the products.

10 2. The apparatus of claim 1 wherein said zones are separated by trays.

3. The apparatus of claim 1 further including heat exchangers disposed exteriorly of said vessel in thermal flow communication with the products within said vessel.

15 4. The apparatus of claim 1 further including a first catalytic material disposed in said first reactor and a second catalytic material disposed in said second reactor.

5. The apparatus of claim 4 wherein said first and second catalytic materials are different.

20 6. The apparatus of claim 5 wherein said first and second catalytic materials are different either in amount, concentration, formulation or configuration.

7. The apparatus of claim 5 wherein said first catalytic material is tailored to produce primarily a first product and said second catalytic material is tailored to produce primarily a second product.

8. The apparatus of claim 1 further including a first heater in said first zone and a second heater in said second zone.

9. The apparatus of claim 8 wherein said heaters are heating coils which are individually controlled.

10. The apparatus of claim 1 further including a third zone with no catalytic material.

11. The apparatus of claim 1 wherein said first zone has conditions optimized for primarily one product and said second zone has conditions optimized for primarily another product.

12. The apparatus of claim 1 further including first and second feed lines communicating with first and second reactors, respectively, and first and second product lines exiting said first and second stages, respectively.

13. The apparatus of claim 12 wherein chemicals passing into first and second feed lines have different molar ratios.

14. The apparatus of claim 12 wherein products exiting first and second product lines have primarily different hydrocarbon chains.

15. The apparatus of claim 1 further including reflux lines communicating between said first
5 and second zones.

16. The apparatus of claim 1 wherein said first and second zones have different conditions.

17. The apparatus of claim 16 wherein said first and second zones are different either in
10 temperature, pressure or catalytic material.

18. The apparatus of claim 1 wherein liquid products migrate in one direction and gaseous
products migrate in another direction through said zones.

19. The apparatus of claim 1 further including a water separator communicating with said
15 vessel.

20. The apparatus of claim 1 further including a paraffin separator communicating with said
vessel.

21. The apparatus of claim 1 wherein said vessel has a varying cross-sections.

22. The apparatus of claim 1 wherein said reactors and distillation stages operate simultaneously.

23. The apparatus of claim 1 wherein said first reactor produces first and second products and
5 said second reactor produces substantially only said first product.

24. A catalytic distillation reactor comprising:

a reaction vessel having a plurality of distillation zones and a catalytic material in each of
said distillation zones.

25. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst
materials comprises a fixed bed.

26. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst
materials comprises a fluidized bed.

27. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst
materials comprises a slurry bed.

28. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst
materials comprises a honeycomb monolith.

29. A catalytic distillation reactor according to claim 24 wherein each catalyst material is selected from the group consisting of fixed bed, fluidized bed, slurry bed, slurry bubble column and ebulliating bed.

5 30. A catalytic distillation reactor according to claim 24 wherein said catalyst material further comprises a metal catalyst selected from the group consisting of iron and cobalt.

31. A catalytic distillation reactor according to claim 24 further comprising a plurality of feed lines.

32. A catalytic distillation reactor according to claim 24 further comprising a plurality of product lines.

33. A catalytic distillation reactor according to claim 24 further comprising a reflux line or a recycle line.

34. A catalytic distillation reactor according to claim 24 further comprising means for cooling, wherein said means for cooling is positioned external to said reaction vessel.

20 35. A catalytic distillation reactor according to claim 24 wherein the diameter of said reaction vessel varies with respect to position along the axis of said reaction vessel.

36. A catalytic distillation reactor according to claim 24 wherein said reaction vessel further comprises a plurality of trays, wherein said trays are substantially perpendicular to the axis of said reaction vessel.

37. A catalytic distillation reactor according to claim 24 wherein said reaction vessel further comprises a plurality of trays, wherein said trays are positioned at an incline with respect to the axis of said reaction vessel.

38. A catalytic distillation reactor according to claim 24 further comprising a heating unit.

39. A catalytic distillation reactor according to claim 24 wherein at least one of said distillation zones comprises a tray with at least one of the following: bubble caps, weirs, filters, sieves, or sintered metal sieves.

40. A catalytic distillation reactor according to claim 24 wherein one of said distillation zones further comprises a heating unit.

41. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst materials comprises a catalyst selected from the group consisting of Mn, Fe, Co, Ni, Tc, Ru, Rh, Pd, Re, Os, Ir, and Pt.

42. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst materials comprises a catalyst support selected from the group consisting of silica, titania,

titania/alumina, alumina, zirconia, aluminum fluoride, fluorided aluminum, fluorided silica, fluorided titania, and fluorided titania/alumina.

43. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst materials comprises a Co or Ru containing catalyst and a promoter selected from the group consisting of Sc, Y, La, Ti, Zr, Hf, Rh, Pd, Os, Ir, Pt, Re, Nb, Cu, Ag, Mn, B, P, and Ta.

44. A catalytic distillation reactor according to claim 24 wherein at least one of said catalyst materials comprises an Fe containing catalyst and a promoter selected from the group consisting of Na, K, Rb, Cs, Mg, Ca, Sr, and Ba.

45. A catalytic distillation reactor according to claim 24 wherein said catalyst materials are in the form of at least one of the following: particles, pellets, monoliths, honeycombs, packed bed, foams, or aerogels.

46. A catalytic distillation reactor according to claim 24 wherein said catalyst materials substantially completely fill said distillation zones.

47. A catalytic distillation reactor according to claim 24 wherein said catalyst materials do not substantially completely fill said distillation zones.

48. A catalytic distillation reactor according to claim 24 wherein the diameter of said reaction vessel is substantially constant.

49. A catalytic distillation reactor for Fischer-Tropsch synthesis of hydrocarbons comprising:
a reaction vessel;
a plurality of trays, said trays disposed inside said reaction vessel at a plurality of vertical
5 locations so as to divide said reaction vessel into a plurality of reaction chambers;
at least one catalyst material positioned above at least one of said trays;
a plurality of feedlines entering said reaction vessel, said feedlines positioned so as to
deposit materials in one or more of said reaction chambers;
a plurality of product lines, said product lines positioned so as to remove materials from
10 one or more of said reaction chambers; and
an exchanger for transferring heat, said exchanger being external to said vessel.

50. A method for the Fischer-Tropsch synthesis of hydrocarbons comprising,
providing a catalytic distillation reactor comprising a reaction vessel, a plurality of
15 distillation zones inside said reaction vessel, and a plurality of catalyst materials disposed
in said distillation zones;
injecting reactants into said catalytic distillation reactor and removing hydrocarbon
products from said catalytic distillation reactor.

20 51. A method for producing hydrocarbons according to claim 50 wherein said reactants
comprise hydrogen and carbon monoxide.

52. A hydrocarbon product produced by the process of claims 50.

53. A method for controlling the Fischer-Tropsch synthesis of hydrocarbons, said method comprising:

providing a catalytic distillation reactor comprising a reaction vessel, a plurality of
5 distillation zones inside said reaction vessel, and a plurality of catalyst materials disposed
in said distillation zones;

selecting a catalyst material for each distillation zone so as to optimize the synthesis of
hydrocarbons in said distillation zone;

controlling the temperature in each distillation zone so as to optimize the synthesis of
10 hydrocarbons in said distillation zone; and

controlling the pressure in each distillation zone.

54. The method of claim 53 wherein said pressure in a distillation zone is from about 80 psig
to about 1000 psig.

55. The method of claim 53 wherein said pressure in a distillation zone is from about 80 psig
to about 600 psig.

56. The method of claim 53 wherein said pressure in a distillation zone is from about 140
20 psig to about 400 psig.

57. The method of claim 53 wherein said pressure in a distillation zone is about 150 psig.